ECOLOGICAL RESTORATION OF AN OLD-GROWTH LONGLEAF PINE STAND UTILIZING PRESCRIBED FIRE

J. Morgan Varner, III, John S. Kush, and Ralph S. Meldahl
School of Forestry, 108 M. White Smith Hall, Auburn University, AL 36849

ABSTRACT

Ecological restoration using prescribed fire has been underway for 3 years in an uncut, old-growth longleaf pine (*Pinus palustris*) stand located in south Alabama. The longleaf pine ecosystem requires frequent (once every 1–10 years) surface fire to prevent succession to later seral stages. Before this study began, this stand had not burned in >45 years, resulting in heavy litter accumulation (>25 centimeters), a dense hardwood mid-story, and few herbaceous species. Baseline data were collected prior to reintroduction of fire into the 23-hectare stand in 1995. Since hardwood stems were removed in a fuelwood operation and fire was reintroduced, litter depth and composition of herbaceous and woody species have changed significantly. Prescribed fire has been used to reduce litter layers, encourage establishment of herbaceous vegetation, discourage survival of hardwood species, deter non-native species establishment and persistence, and alter residual longleaf pine stand structure. Analysis of data collected prior to the onset of restoration and 4 years later shows highly significant changes in surface soil nutrients, litter depths, and herbaceous species establishment, as well as substantial longleaf pine mortality.

keywords: ecological restoration, longleaf pine, mortality, nutrients, old-growth, *Pinus palustris*, prescribed fire, south Alabama.

Citation: Varner, J.M., III, J.S. Kush, and R.S. Meldahl. 2000. Ecological restoration of an old-growth longleaf pine stand utilizing prescribed fire. Pages 216–219 *in* W. Keith Moser and Cynthia F. Moser (eds.). Fire and forest ecology: innovative silviculture and vegetation management. Tall Timbers Fire Ecology Conference Proceedings, No. 21. Tall Timbers Research Station, Tallahassee, FL.

INTRODUCTION

Prior to European settlement, forested savannas dominated by longleaf pine and the most diverse herbaceous layer in temperate North America blanketed an estimated 37 million hectares in the southeastern United States. These forests, termed "savannas" for their open, parklike nature, were swept by fire once every 1–10 years (Mattoon 1922, Chapman 1932, Christensen 1981). Due to fire suppression, agriculture, and site conversion, longleaf forests exist today on <3% of their former range (Frost 1993). A 1995 U.S. Biological Survey Report listed the longleaf pine forest as the third most endangered ecosystem in the United States (Noss et al. 1995). Old-growth longleaf pine forests exist in an even more imperiled state, covering <4,000 hectares, or 0.0001% of their former extent (Means 1995). Recent harvests of portions of the remaining old-growth area make the study of ecological restoration of old-growth longleaf pine forests more urgent.

Restoration of pre-Columbian forest conditions in North America is becoming a major topic in natural resource management (Hermann 1993, Landers et al. 1995, Covington et al. 1997). Ecological restoration is the process of assisting the recovery and management of ecological integrity. Ecological integrity includes a critical range of variability in biodiversity, ecological processes and structures, regional and historical context, and sustainable cultural practices (Society for Ecological Restoration 1996). Ecological restoration in the longleaf pine forests of the southeastern United States has recently been undertaken by private, state, and federal land managers. Restoration managers to this point have lacked an understanding of interactions that occur during restoration. Both scientists and managers need more information on reducing litter accumulations, soil elemental dynamics, herbaceous species establishment, and changes in overstory structure during restoration.

The impacts of ecological restoration on longleaf pine forests are being studied in the Flomaton Natural Area in Escambia County, Alabama. The importance of the stand was recognized by the Society of American Foresters (SAF) in 1963 when SAF named the area the E.A. Hauss Old Growth Longleaf Natural Area (Walker 1963). SAF's definition of a natural area is "a tract of land set aside to preserve permanently in unmodified condition a representative unit of virgin growth of a major forest type, with the preservation primarily for scientific and educational purposes" (Walker 1963).

The Flomaton Natural Area is a 23-hectare virgin longleaf pine stand that prior to this study was protected from fire for >45 years. In 1993, an agreement was signed among Champion International Corporation, owner of the stand; Auburn University School of Forestry; the Southern Research Station of the U.S. Department of Agriculture, Forest Service; The Nature Conservancy; the Alabama Forestry Commission; and the Alabama Natural Heritage Trust of the Alabama Department of Conservation and Natural Resources for cooperative work (Meldahl et al. 1994). Efforts are underway to restore, monitor, and manage the 23-hectare stand as an old-growth longleaf pine ecosystem.

Restoring fire to fire-suppressed longleaf pine stands like the Flomaton Natural Area is necessary to reduce pine litter layers, encourage establishment of longleaf pine seedlings and native herbaceous species, and discourage survival of hardwoods and non-native species. Ecological restoration of the Flomaton Natural Area using prescribed fire began in 1993. The first prescribed fire was conducted in the stand in 1995 (one-half in January, the other in May). Subsequent prescribed burns were conducted in 1996 (the opposite half in January, the other in May). The June 1997 burn began a period of burning the entire stand on a single day.

METHODS

The study area is in the Flomaton Natural Area, located in Escambia County, Alabama, (31°01′ N; 87°15′ W), 63 meters above mean sea level. The climate is humid and mild with abundant rainfall (mean annual precipitation = 156 centimeters) well distributed throughout the year. The warmest months are July and August with average daily maximum and minimum temperatures of 33° and 20°C, respectively. The coldest months are December and January with average daily maximum and minimum temperatures of 18° and 3°C, respectively. The predominant soil series is the Orangeburg (Typic Paleudult, fine-loamy siliceous thermic). This soil formed in marine sediments of sandy loams and sandy clay loams. It is low in natural fertility and organic-matter content (Mattox 1975).

Prior to the onset of restoration efforts, permanent 0.08-hectare plots were established on a 60 × 80-meter grid within the stand. Within each plot, all longleaf pines >2 centimeters in diameter at breast height (DBH) were located by an azimuth reading and distance from plot center. Crown height, total height, crown class, and DBH of live trees and standing snags, and litter depth at the base of each tree, were measured in 1993. Litter depths and tree DBH were measured again in 1997. Where possible, cause of mortality was determined.

In 1994, 1995, and 1997, 4 soil samples were taken on each plot at a depth of 3–7 centimeters and composited. These soil samples were analyzed for macro- and microelement content using an inductively-coupled argon plasma (ICAP) spectrometer. Most elements were measured in units of parts per million (ppm). Nitrogen and carbon were measured as percentages.

Additionally, each plot contains 4 permanent 1.42-square meter herbaceous quadrats. Each quadrat has been surveyed for plant species occurrence quarterly since March 1993 (2 years preburn). Species names follow Radford et al. (1968).

A fuelwood harvest of all hardwoods occurred in April and May 1996. The operation removed 1,227 metric tons of hardwood chips and did very little damage to the residual stand.

RESULTS AND DISCUSSION

Longleaf pine mortality following 3 prescribed fires (1995, 1996, and 1997) and fuelwood removal

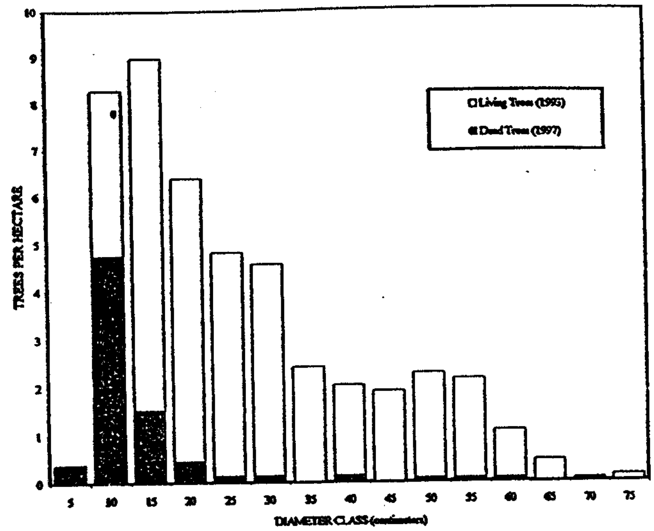

Fig. 1. Diameter distribution of all longleaf pine in 1993, and their status in 1997 following 3 prescribed fires and a fuelwood harvest operation at the Flomaton Natural Area, AL.

(1996) has been substantial, especially in the lowest diameter classes (Figure 1). Annual mortality for all longleaf pine over the study period averaged 4.2%. However, it was 100% for all sampled trees <7.5 centimeters DBH. Platt and Rathbun (1993) also observed highest mortality in trees <10 centimeters DBH, but annual mortality ranged from only 3.2–11.6% in their 8 years of sampling. Our high levels of mortality contrast sharply with prior observations from <1% (Boyer 1979, Palik and Pederson 1996) up to 2% annual mortality when large-scale disturbances are included in long-term studies (Platt and Rathbun 1993). Reasons for this disparity are poorly understood. In addition, although other studies have observed ingrowth that exceeded mortality (Platt and Rathbun 1993), no tree stratum ingrowth occurred over the 4-year measurement period. Perhaps restoration efforts, even when applied responsibly, have a much more pronounced and long-term effect than has been previously supposed.

The causes of longleaf pine mortality also differed from prior reports. Suppressed trees accounted for 41% of total mortality. It seems unlikely that these overtopped trees that survived crown closure and belowground competition during the period prior to restoration (Meldahl et al. 1999) would suddenly all die from overstory suppression after restoration began. Perhaps the stresses from fire accelerated patch break-up and thinning. Other causes of mortality included fire (17%), mechanical (14%), beetles (8%), lightning (3%), wind (2%), and disease (2%). Thirteen percent of mortality could not be explained. In previous studies, lightning strikes and wind throw have been the most common causes of mortality (Boyer 1979, Platt and Rathbun 1993, Palik and Pederson 1996). The inclusion of smaller trees in this study probably explains this deviation.

Basal area did not change (17.9 to 17.8 square meters per hectare) from 1993–1997. Considering the

Table 1. Litter depth comparison for the Flomaton Natural Area, AL, prior to prescribed burning (1993) and after 3 prescribed burns (1997).

Diameter at breast height (DBH) Class (centimeters)	1993 (preburn)	1997 (after 3 burns)	% Decrease
	------- (centimeters) --------		
5	14.22	10.03	29.5
10	13.26	11.00	17.0
15	15.23	11.35	25.3
20	14.84	11.17	24.7
25	15.00	11.76	21.6
30	17.91	12.25	31.6
35	20.07	13.82	31.1
40	19.94	14.27	28.4
45	21.48	16.00	25.5
50	24.33	16.54	32.0
55	24.18	16.88	30.2
60	26.22	18.60	29.1
65	25.82	17.78	31.1
70	19.69	12.70	35.5

high rate of mortality and an added complication of bark consumption by fire (reducing diameter of large trees inordinately more than smaller trees), this figure is noteworthy. Mean DBH of all longleaf pine increased from 24.0 to 27.5 centimeters from 1993–1997. Tree density decreased from 280 trees per hectare (TPH) in 1993 to 230 TPH in 1997.

After 3 prescribed fires, pine litter depths were significantly reduced (t-test, $P < 0.001$) and less variable (1993 variance = 18.6; 1997 = 9.1). While the 3 fires have reduced litter depth, a heavy accumulation still exists (Table 1). At the onset of restoration efforts in the Flomaton Natural Area, pine needle litter depths at the bases of trees could support potentially lethal fires. Pine litter becomes a threat when (1) heavy amounts accumulate under large trees, and (2) feeder roots invade this rich organic layer. Fire becomes lethal when it kills a large portion of the feeder roots or the basal litter burns with sufficient intensity to girdle the tree. For example, in 1993 a trash fire escaped and burned an abutting portion of the stand. Due to the heavy litter accumulations in this unburned portion, the largest trees were girdled at their bases from the heat generated by the burning litter (Kush et al. 1999).

In the 45 years in which fires were eliminated from the Flomaton Natural Area, herbaceous species abundance and diversity plummeted. After hardwood removal (1996) and 3 prescribed fires (1995, 1996, and 1997), the measured herbs increased from 1 species (*Euphorbia corollata*) in 1993 to 23 in 1997 (Table 2). This increase was due to the reduction in litter depths and increased canopy openness caused by the hardwood harvest and prescribed fires, thereby creating an environment more favorable to herbaceous species establishment and survival. Additionally, a possible explanation for this striking increase may be seed storage in a seed bank present in the stand. The isolation of the stand from other forests and its proximity to residential and cultivated land make the resurrection of these native herbaceous species bewildering. Aside from the substantial increases observed in herbs, other

Table 2. Plant species occurrence in the Flomaton Natural Area, AL, plots prior to prescribed burning (1993) and after 3 prescribed burns (1997). Nomenclature follows Radford et al. (1968).

Species	Year 1993	Year 1997
Acalypha virginica		X
Albizia julibrissin	X	X
Ambrosia artemisiifolia		X
Antennaria plantaginifolia		X
Andropogon virginicus		X
Aster spp.		X
Callicarpa americana		X
Cassia fasiculata		X
Carex spp.		X
Cyperus spp.		X
Dioscorea villosa		X
Elephantus tomentosous		X
Euphorbia corollata	X	X
Eupatorium compositifolium		X
Gelsemium sempervirens	X	X
Gnaphalium obtusifolium		X
Habenaria ciliaris		X
Hypericum hypercoides		X
Ilex americana	X	X
Ilex decidua	X	X
Ilex glabra	X	X
Ilex vomitoria	X	X
Ipomea purpurea		X
Ligustrum sinense	X	X
Liatris squarosa		X
Liatris tenuifolia		X
Lonicera japonica	X	X
Magnolia grandiflora	X	X
Magnolia virginiana	X	X
Melia azedarach	X	X
Myrica cerifera	X	X
Nyssa sylvatica	X	X
Osmanthus americana	X	X
Oxalis spp.		X
Parthenocissus quinquefolia	X	X
Panicum spp.		X
Pinus echinata	X	X
Pinus glabra	X	X
Pinus palustris	X	X
Pinus taeda	X	X
Phytolacca americana		X
Phlox carolina		X
Prunus serotina	X	X
Pueraria montana		X
Quercus falcata	X	X
Quercus laurifolia	X	X
Quercus margaretta	X	X
Quercus nigra	X	X
Rhus copallina	X	X
Rhus radicans	X	X
Rhus toxicodendron	X	X
Rubus spp.	X	X
Sassafras albidum	X	X
Sapium sebiferum	X	X
Smilax bona-nox	X	X
Smilax glauca	X	X
Smilax laurifolia	X	X
Smilax pumila	X	X
Smilax rotundifolia	X	X
Smilax smallei	X	X
Solidago odorata		X
Vaccinium arboreum	X	X
Vaccinium elliottii	X	X
Vitis rotundifolia	X	X
Total herbs	1	23
Total woody vines	13	13
Total shrubs	9	11
Total trees	17	17
Total non-natives	5	6
Total species	40	64

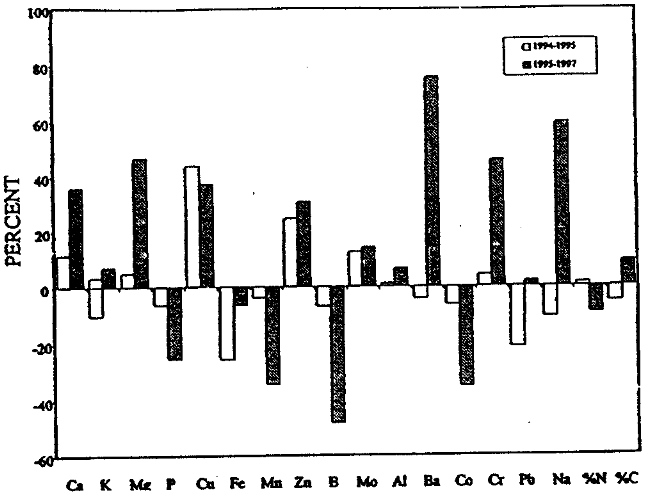

Fig. 2. Soil element change (%) after 3 prescribed fires and a fuelwood harvest operation at the Flomaton Natural Area, AL.

categories (e.g., woody vines and trees) showed little change in occurrence. Most other seasonal sampling of herbaceous quadrats will continue.

Soil nutrient dynamics following 3 years of prescribed burning at Flomaton Natural Area have been dramatic (Figure 2). All elemental contents measured, except carbon, nitrogen, and potassium, have significantly changed (t-test, $\alpha = 0.05$). Large increases (>40%) have been observed in copper, barium, zinc, magnesium, calcium, and chromium. Losses have been the greatest (>30%) in boron, cobalt, and manganese. For several elements, responses have been variable; that is, they increased after the first fire, then decreased after the third. Owing to this extreme variability in soil nutrient response, speculation after only 4 years would be premature. Further analysis and measurements are planned to follow soil elemental change during the ecological restoration process.

ACKNOWLEDGMENTS

The authors thank Champion International Corporation and F. Dickard for allowing the restoration process to occur in the Flomaton Natural Area. Additionally, we thank R.K. Sampson, D.J. Shaw, W. Williams, N. Gupta, L.L. Pitt, F.B. Yanquoi, D. Greco, G.A. Ward, W. Thompson, R.K. Tucker, D. Wade, and W.S. Hauffe for their efforts in restoring the Flomaton Natural Area. Comments by an anonymous reviewer greatly improved an earlier draft of this manuscript.

LITERATURE CITED

Boyer, W.D. 1979. Mortality among seed trees in longleaf pine shelterwood stands. Southern Journal of Applied Forestry 3:165–167.

Chapman, H.H. 1932. Is the longleaf type a climax? Ecology 13:328–334.

Christensen, N.L. 1981. Fire regimes in southeastern ecosystems. Pages 112–136 *in* H.A. Mooney, T.M. Bonnicksen, N.L. Christensen, J.E. Lotan, and W.A. Reinsers (eds.). Fire regimes and ecosystem properties. General Technical Report WO-26, U.S. Department of Agriculture, Forest Service, Washington Office, Washington, DC.

Covington, W.W, P.Z. Fulé, M.M. Moore, S.C. Hart, T.E. Kolb, J.N. Mast, S.S. Sackett, and M.R. Wagner. 1997. Restoring ecosystem health to ponderosa pine forests of the Southwest. Journal of Forestry 95:23–29.

Frost, C.C. 1993. Four centuries of changing landscape patterns in the longleaf pine ecosystem. Tall Timbers Fire Ecology Conference Proceedings 18:17–44.

Hermann, S.M. (editor) 1993. The longleaf pine ecosystem: ecology, restoration, and management. Tall Timbers Fire Ecology Conference Proceedings 18.

Kush, J.S., J.M. Varner, and R.S. Meldahl. 1999. Slow down, don't burn too fast, got to make that old-growth last... Pages 109–111 *in* J.S. Kush (compiler). Proceedings of 2nd Longleaf Alliance conference. Nov. 19–22, 1998, Charleston, SC. Longleaf Alliance Report No. 4.

Landers, J.L., D.H. Van Lear, and W.D. Boyer. 1995. Longleaf pine forests of the Southeast: requiem or renaissance? Journal of Forestry 93:39–44.

Mattoon, W.R. 1922. Longleaf pine. U.S. Department of Agriculture Bulletin 1061.

Mattox, M.G. 1975. Soil Survey of Escambia County, Alabama. U.S. Department of Agriculture, Soil Conservation Service, Washington, DC.

Means, D.B. 1995. Longleaf pine forest, going, going, . . . Pages 210–229 *in* M.B. Davis (ed.). Eastern old-growth forests: prospects for rediscovery and recovery. Island Press, Washington, DC.

Meldahl, R.S., J.S. Kush, D.J. Shaw, and W.D. Boyer. 1994. Restoration and dynamics of a virgin, old-growth longleaf pine stand. Pages 532–533 *in* Proceedings, Annual Convention. Society of American Foresters, Bethesda, MD.

Meldahl, R.S., N. Pederson, J.S. Kush, and J.M. Varner. 1999. Dendrochronological investigations of climate and competitive effects on longleaf pine growth. Pages 265–285 *in* R. Wimmer and R.E. Vetter (eds.). Tree-ring analysis: biological, methodological, and environmental aspects. CAB International, Wallingford, UK.

Noss, R.F., E.T. LaRoe, III, and J.M. Scott. 1995. Endangered ecosystems of the United States: a preliminary assessment of loss and degradation. Biological Report 28, U.S. Department of the Interior, National Biological Service, Washington, DC.

Palik, B.J., and N. Pederson. 1996. Overstory mortality and canopy disturbances in longleaf pine ecosystems. Canadian Journal of Forest Research 26:2035–2047.

Platt, W.J., and S.L. Rathbun. 1993. Population dynamics of an old-growth population of longleaf pine (*Pinus palustris*). Tall Timbers Fire Ecology Conference Proceedings 18:275–298.

Radford, A.E., H.E. Ahles, and C.R. Bell. 1968. Manual of the vascular flora of the Carolinas. University of North Carolina Press, Chapel Hill.

Society for Ecological Restoration. 1996. Society for Ecological Restoration Policy Working Group definition. http://www.ser.org/definitions.html.

Walker, L.C. 1963. Natural areas of the Southeast. Journal of Forestry 61:670–673.